§8. Relation between High-n and Low-n Ballooning Modes in Currentless $L=2$ Heliotron/Torsatrons

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As mentioned in the report entitled "Characteristics of the high-n ballooning modes in currentless $L = 2$ heliotron/torsatrons", there are two types of high-n ballooning modes, i.e., stellarator-like modes and tokamak-like modes with being dependent on whether the local magnetic curvature due to the helicity overcomes that due to the toroidicity or not.

In the case of the tokamak-like high-n ballooning modes, the dependence of the eigenvalue on the field line label is so weak that those modes do not localize in the toroidal direction. Thus, the toroidal mode numbers of the low-n ballooning modes corresponding to the tokamak-like high-n ballooning modes may be fairly good quantum numbers. Therefore, the stellarator expansion using the average in the toroidal direction may be applicable to those modes. As those high-n modes become unstable in the region where the local magnetic curvature due to the helicity is weak compared with that due to the toroidicity, the corresponding low-n ballooning modes will be localized near the magnetic axis with a tokamak-like global magnetic shear for the equilibrium with peaked pressure profile, e.g., $P = P_0(1 - \psi_N)^2$ where ψ_N is the normalized toroidal flux. The global shear near the magnetic axis is so weak that low-n modes have the fairly large toroidal mode number. Since the radial extension of the each quasi-mode (corresponding to the high-n ballooning modes) constructing the low-n modes is thought to become so narrow that the stabilizing effects by the Finite Larmor Radius (FLR) effects may become significant.

In contrast with it, in the case of the stellarator-like high-n ballooning modes, the dependence of the eigenvalue on the field line label is so strong that those modes localize in the both poloidal and toroidal directions. Note that there are stable region outside of torus in the toroidal direction. As those high-n modes become unstable in the region where the local magnetic curvature due to the helicity is strong compared with that due to the toroidicity, the corresponding low-n ballooning modes will be localized near the plasma periphery with a stellarator-like global magnetic shear for the equilibrium with peaked pressure profile, e.g., $P = P_0(1 - \psi_N)^2$. The toroidal mode numbers of the low-n ballooning modes corresponding to the stellarator-like high-n ballooning modes are not good quantum numbers and the stellarator expansion using the average in the toroidal direction is not applicable to those modes. Because the low-n ballooning modes in tokamaks consist of many quasi-modes with the same toroidal mode number in order to represent the localization in the poloidal direction, many quasi-modes with the same poloidal mode number are required in order to represent the localization in the toroidal direction. Letting i be the minimum toroidal mode number of the quasi-modes constructing the low-n modes, the other toroidal mode number of the quasi-modes consists of i, $i + M$, $i + 2M$, $i+3M$, $i+4M$, $\cdots$ where M is the toroidal pitch number of the equilibrium. Since the minimum toroidal mode number i may be the order of M in order for the low-n modes to localize in the unstable region in the toroidal direction, the toroidal mode number of the dominant quasi-mode with the maximum amplitude is about 50 for LHD letting the toroidal mode number of the dominant quasi-mode be $i+4M$. Therefore, the FLR stabilizing effects become significant.

Which type of ballooning mode between tokamak-like and stellarator-like one occurs depends on which type of magnetic curvature between due to toroidicity and due to the helicity is dominant. Therefore, the pressure profile influencing the deformation of the flux surfaces through the Shafranov shift makes the situation of the high-n and low-n ballooning modes change. For broader pressure profile, e.g., $P = P_0(1 - \psi_N^2)^2$, the tokamak-like ballooning modes occur in the stellarator-like global magnetic shear region.